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MODERN COSMOLOGY AND SOME IMPLICATIONS FOR RELIGION*

Joel Primack

Throughout history cultures have adopted cosmological myths as a means to understand the world and the place of human beings in that world. Since the time of Galileo and Descartes the cosmological myths of religion were permanently divorced from the cosmological accounts grounded in the natural sciences. Nonetheless, even contemporary scientific cosmology can act as a controlling metaphor for thinking about humanity and its fate.

Introduction

Modern cosmology — the study of the universe as a whole — is undergoing a scientific revolution. New ground and space-based telescopes can now observe every bright galaxy in the universe, and see back in time to the cosmic dark ages before galaxies formed. We can read the history of the early universe in the ripples of heat radiation still arriving from the Big Bang. What is emerging is humanity's first story of the origin and nature of the universe that might actually be true.

Ever since Descartes recommended splitting the study of human meaning from the study of the material world in order to protect science and religion from each other, it has been traditional in Western thought to ignore cosmology in thinking about the cultural universe. This was partly a reaction to the uncertainty of cosmology, which in the absence of reliable data had long been the most speculative of sciences. This is no longer true. Big Bang cosmology was one of the great discoveries of the twentieth century, and it is high time to rethink the human role in terms of it.

We like to think of our generation as the most knowledgeable that has ever lived. And yet most people in modern Western culture have no idea what our universe looks like, or how to begin to think about the way we humans may fit into it. Every traditional culture known to anthropology has had a cosmology — a shared story of how the world began and continues, how humans came to exist, and what the gods expect of us. Cosmology made sense of the ordinary world by defining a larger context and grounding people's sense of reality, their identity, and their codes of behavior in that grand scheme. Like modern science, it embedded everydayness in an invisible reality. Modern science explains by means of countless molecules; African cosmologies explain by means of countless



spirits.¹ Ordinary people in traditional societies accepted responsibility for maintaining the cosmos itself by ritually re-enacting the creation stories for every generation. This is how they knew who they were. For many ancient peoples, no value was higher than maintaining harmony between the way the universe is and the way human beings behave. The absence of a cosmology was as inconceivable as the absence of language. Their pictures of the universe were not what anyone today would consider scientifically accurate, but they were true by the standards of their culture.

Science undermined all traditional pictures of the universe in the Renaissance, centuries before it was in a position to create one of its own. A cosmology can only be taken seriously if it is believable, and after the scientific revolution our standards of believability were forever changed. For four centuries cosmology was not taken seriously because the ratio of theory to data was almost infinite. However, science now appears to be closing in on an origin story that can withstand the most rigorous tests, one that will still be accepted hundreds of years from now, as Newton's theory remains valid (within known limitations) on the scale of the solar system.

A new scientific theory may be said to encompass an old one when the new theory is valid for a wider class of phenomena, and the new theory reduces to the old one for a subset of these phenomena — that is, the two theories make the same predictions (to some specified accuracy). Charles Misner has pointed out a deep insight about scientific truth: the only sort of theory we can know to be “true” is one which has been shown to be false — in the sense that its limitations are known. As philosophers of science from Hume to Popper have emphasized, we can never prove that a scientific theory is true, since there is always the possibility that new data will be discovered that disprove it. But when a scientific theory has been encompassed by a more comprehensive theory that itself has been well tested, we can have considerable confidence that the encompassed theory is “true” within its known limits. This is the highest grade of truth possible in modern science.²

Modern cosmology is now building a lasting scientific foundation, as the simplest version of the Big Bang theory is encompassed by more comprehensive theories such as cosmic inflation. New instruments such as the Hubble Space Telescope, the Keck Observatory in Hawaii, and the Wilkinson Microwave Anisotropy Probe are producing the first detailed data about the distant universe. Of course, we see celestial objects as they were when their light left them. Since light travels at a finite speed, looking out in space is the same as looking back in time. We can now observe every bright galaxy in the visible universe, and even look back to the cosmic dark ages before galaxies had formed. The physical past of the universe on the largest scales has not been erased by time, but is largely recorded in the heat radiation still arriving from the Big Bang. In the patterns of the subtle temperature differences in the cosmic background radiation in different directions we are learning to read the Genesis story of the expanding universe.

The resulting origin story will be the first ever based on scientific evidence, and the first ever created by a collaboration of people from different religions and races all around the world, all of whose contributions are subjected to the same standards of verifiability. The new picture of reality excludes no one and treats all humans as equal. The revolution in scientific

cosmology today may open the door to a believable picture of the larger reality in which our world, our lives, and all our cultures are embedded.

Religion and Cosmology

In Biblical times when people looked up at a blue sky, they understood the blue to be water, held up by a hard, transparent dome that covered the entire flat earth.³ In the King James translation, the dome was named the "firmament." According to the first creation story at the beginning of Genesis, by creating this dome on the second day, God divided the waters "above" from the waters "below" and held open the space for dry land and air. Only if this is appreciated can one see that when God opened the chimneys of heaven and the fountains of the deep in the Noah flood, it caused not just a big rainstorm, but a cosmic catastrophe that threatened to undo creation itself.

At about the same time as the Genesis story took the form in which we know it, Greek philosophers a few hundred kilometers away were living in a different universe in which the earth was not flat and domed but a round celestial object. By the Middle Ages⁴ the Greek image of concentric spheres, and not the Bible's flat domed earth, had become the unquestioned universe for Jews, Moslems, and Christians alike.

Thus on a clear night in medieval Europe, a person looking up into the cathedral of the sky would have seen hard, transparent spheres nested inside each other, encircling the center of the universe, the earth. Each sphere carried a planet, the moon, or the sun. Heaven itself was immediately outside the most distant sphere, which carried the "fixed stars." The hierarchies of church, nobility, and family mirrored this cosmic hierarchy. Every thing and every creature in the universe tended toward its proper place for the love of God.

The stable center was torn out of the medieval universe at the beginning of the 17th century, when Galileo's observations with his new telescope showed that the Ptolemaic earth-centered picture was wrong.⁵ Galileo ridiculed the prevailing cosmology in his *Dialogue Concerning the Two Chief World Systems* (1632), but the Catholic Church forced him to recant and held him under house arrest for the rest of his life. This was a frightening and sobering event for scientists all over Europe. Eventually, following the lead of Bacon and Descartes, science protected itself by entering into a de facto pact of noninterference with religion: science would restrict its authority to the material world, and religion would hold unchallenged authority over spiritual issues. By the time Isaac Newton was born in 1642, the year of Galileo's death, the spoils of reality had been divided. The physical world and the world of human meaning were now two separate realms.

The new picture portrayed the universe as endless empty space with stars scattered randomly in it. This picture never fully replaced the medieval universe in people's hearts, partly because it felt so incomplete. Space couldn't be infinite, or the night sky would be white with stars.⁶ But it couldn't be finite, or the newly discovered force of gravity would cause it to collapse to its center.⁷ There was no particular place for humans, no place for God, and no explanation of its origin. In the mid-17th century, Blaise

Pascal expressed a sentiment unheard of in the Middle Ages: “engulfed in the infinite immensity of spaces whereof I know nothing and which know nothing of me, I am terrified.... The eternal silence of these infinite spaces alarms me.”⁸ Newtonian cosmology was the first that had nothing to say about humans, and believers in science could no longer even conceptualize the ancient ideal of humans living in harmony with the universe.

Why should an origin story matter today? “The universe” is irrelevant to most people in the West, except as a fantasy outlet. Novels about it are classified as science fiction, something we are not expected to take seriously. The universe plays no part in mainstream religions, except perhaps to demonstrate the glory of a creator. How many people recognize the possibility of a sacred relationship between the ways the expanding universe operates and the way human beings ought to behave? What religion teaches that this could be a source of harmony among humans?

Instead most educated people in the 21st century live in a cosmology defined by a 17th century picture of cold, still, empty space, along with fragments of traditional stories and doubts everywhere about what is real. Many have not fully absorbed the discovery nearly a century ago of the great age and size of the universe;⁹ indeed, controversies between science and religion often center on conflicting origin stories. The educated public needs to appreciate that, like the experimental sciences, the “historical sciences” — archaeology, evolutionary biology, geology, and cosmology — are producing reliable knowledge and testing it by its agreement with predictions about new knowledge about the past.

The current cosmological revolution may provide the first chance in 400 years to develop a shared cosmology. There is, however, a moral responsibility involved in tampering with the underpinnings of reality, as scientific cosmology is now doing. How well the emerging cosmology is interpreted in language meaningful to ordinary people may influence how well its elemental concepts are understood, which may in turn affect how positive its consequences for society turn out to be. Will the new scientific story fuel a renaissance of creativity and hope in the emerging global culture — or will it be appropriated by the powerful and used to oppress the ignorant, as the medieval hierarchical universe was used to justify rigid social hierarchies? Will news of new discoveries about the universe just be entertainment for an educated minority but, like science fiction or metaphysics, have little to do with the “real world”?

All possibilities are still open because the meaning of this new cosmology is not implicit in the science. Scientific cosmology, unlike traditional cosmologies, makes no attempt to link the story of the cosmos to how human beings should behave. Nevertheless, the universe is an evolving being, and we are one of the things that it is doing right here and now. This suggests the possibility of links, but making these links is not science. Like a living language, a living cosmology is a collective human creation. It is the job of scholars, artists, and other people of daring creativity to try to understand the scientific picture, and to perceive and express human meanings in it.¹⁰ A living cosmology for 21st century culture will emerge when the scientific nature of the universe becomes enlightening for human beings.

This will not happen easily. The result of centuries of separation

between science and religion is that each is suspicious of the other infringing on its turf. In 1999 the AAAS Program of Dialogue on Science, Ethics, and Religion (DoSER)¹¹ sponsored a 3-day public conference called “Cosmic Questions”¹² at the Smithsonian National Museum of Natural History which asked: Did the universe have a beginning? Was the universe designed? Are we alone? Not surprisingly, no consensus was reached on any of these questions. Although the goal was “constructive dialogue” between science and religion, some of the participants complained that the dialogue went one way — science always demanding that religion adapt to new discoveries. Naturally, science is not about to change its methods to accommodate religious concerns. But a cosmology that does not account for human beings or enlighten us about the role we may play in the universe will never satisfy the demand for a *functional cosmology* that religions have been trying to satisfy for millennia.¹³

I only have space here for one of many possible examples of how the emerging scientific cosmology could provide a basis for a living, functional cosmology for the 21st century that, like ancient cosmologies, can help guide humanity toward harmony with each other and the cosmos. Nancy Abrams and I describe another in our article “Gravity, the ultimate capitalist principle”¹⁴

The Transition from Cosmic Inflation to Expansion as a Model for Earth

Standard Big Bang theory explains the creation of the light elements in the first three minutes,¹⁵ but it does not explain what preceded or what has followed. Gravity alone could not have created the galaxies and the complex large-scale structures and flows of galaxies that are observed to exist. If matter were absolutely evenly distributed coming out of the Big Bang, gravity could have done nothing but affect the rate of the overall expansion. Consequently, either some causal phenomenon such as “cosmic strings” acting after the Big Bang formed the giant structures we observe today — which looks increasingly dubious because such theories conflict with the new observations of the cosmic background radiation — or else gravity must have had some differences in density to work with from the beginning. Cosmic Inflation could have caused such primordial differences.

The theory of Cosmic Inflation was proposed two decades ago by Alan Guth, Andrei Linde, and others. It is the only explanation we have today for the initial conditions that led to the Big Bang.^{16,17} It says that for an extremely small fraction of a second at the beginning of the Big Bang — much less time than it would take light to cross the radius of an atomic nucleus — the universe expanded exponentially, inflating countless random quantum events in the process, leaving the newly created spacetime faintly wrinkled on all size scales. All large structures in the universe today grew from these quantum fluctuations, enormously inflated in scale.

The wrinkles are regions of slightly higher than average density. In their vicinity, space expanded a little more slowly. In consequence, it was in these regions that matter first began to collapse and make galaxies hundreds of millions of years later, beginning the construction of the visible universe. Within the long filaments and great clusters of galaxies that

astronomers observe today, lie the lines of the original blueprint for our universe. All of spacetime is bathed in information — readable by intelligent life — about the subtle wrinkles in the spacetime of the very early universe. The latest observations of the small-angle fluctuations in the temperature of the cosmic background radiation and of the distribution of galaxies all appear to be consistent with the predictions of Cosmic Inflation plus Cold Dark Matter theory¹⁸ with Dark Energy,¹⁹ although more demanding tests are still to come.

Inflation is also the controlling metaphor of our culture in the present epoch. Not only is the human population inflating; so too are the average technological power and the resource use of each individual. For example, the global population has increased by about a factor of four in the past century, and the energy use per capita has increased by about a factor of 25.²⁰ Multiply these times each other: our species is now processing a substantial fraction of the earth's entire crust. In population growth, resource use, pollution, and garbage production, the human race is addicted to exponential growth, but this obviously cannot continue at the present rate. In a finite environment, inflation must end, however cleverly we may postpone or disguise the inevitable. The single most important question for the present generation may be how global civilization can make the transition gracefully from inflating consumption to a sustainable level. No answer has yet been found in normal political processes. As Einstein famously said, "Problems cannot be solved at the same level of awareness that created them." But the cosmic transition from inflation to the slow and steady expansion that followed the Big Bang shows that ending inflation does not mean that all growth must stop, even though many people trying to save the planet assume so. Inflation transformed to expansion can go on for billions of years. Reality is not a zero-sum game, in which a gain one place must be paid for with a loss somewhere else. Processing information does not need to be environmentally costly. Human life can continue to be enhanced as long as our creativity stays ahead of our material growth.

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NOTES

* This is an expanded version of the article "Cosmology and 21st Century Culture," by Nancy E. Abrams and Joel R. Primack, *Science* 293, 1769 (September 7, 2001). I thank Nancy Abrams for collaborating on it. This and other articles by us addressing themes discussed here are available on the web (<http://physics.ucsc.edu/cosmo/primackabrams.html>).

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6. E. R. Harrison, *Darkness at Night: a Riddle of the Universe* (Harvard Univ. Press, Cambridge, MA, 1987).
7. I. Newton, "Letter to Richard Bentley," in Milton Munitz, ed., *Theories of the Universe* (Free Press, Glencoe, IL, 1957), pp. 211-214.
8. B. Pascal, *Pensees*, Sec. III, nos. 205-206.
9. S. E. Toulmin, J. Goodfield, *The Discovery of Time* (Univ. of Chicago Press, Chicago, 1965).
10. My wife Nancy Abrams has tried to do this in *Alien Wisdom*, a CD of her original music, including songs about the themes of this article (see expandinguniverse.org).
11. For more about DoSER see www.aaas.org/spp/dser/. I served as chairman of the DoSER advisory committee 2000-2002.
12. The proceedings of the Cosmic Questions conference are published in *Annals of the NY Academy of Sciences* 950 (2001). A CD-ROM version is about to be published by AAAS, including video of some highlights of the conference and several hours of edited videotaped interviews with the conference speakers.
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15. Steven Weinberg, *The First Three Minutes: A Modern View of the Origin of the Universe* (New York: Basic Books, 1993).
16. For a more detailed explanation of current thinking about the initial conditions for the Big Bang, see, e.g., A. H. Guth, *The Inflationary Universe: the Quest for a New Theory of Cosmic Origins* (Addison-Wesley Publishing, Reading, Mass., 1997); M. Rees, *Before the Beginning* (Addison-Wesley Publishing, Reading, MA, 1997).
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